

**Purdue University**  
**Purdue e-Pubs**

---

International Compressor Engineering Conference

School of Mechanical Engineering

---

1980

# Hermetic Compressor with Brushless DC Motor

F. Sorenson

Follow this and additional works at: <https://docs.lib.purdue.edu/icec>

---

Sorenson, F., "Hermetic Compressor with Brushless DC Motor" (1980). *International Compressor Engineering Conference*. Paper 335.  
<https://docs.lib.purdue.edu/icec/335>

This document has been made available through Purdue e-Pubs, a service of the Purdue University Libraries. Please contact [epubs@purdue.edu](mailto:epubs@purdue.edu) for additional information.

Complete proceedings may be acquired in print and on CD-ROM directly from the Ray W. Herrick Laboratories at <https://engineering.purdue.edu/Herrick/Events/orderlit.html>

## HERMETIC COMPRESSOR WITH BRUSHLESS DC MOTOR

Frode Sørensen  
Danfoss A/S, Nordborg, Denmark

### ABSTRACT

Danfoss has developed and marketed a new hermetic compressor for the 12V and 24V market. The pump is driven by a brushless DC motor with associated external electronics.

Characteristic of the system is the low noise level, the high COP value and electronic protection against under voltage and locked rotor.

The function and features of the compressor will be discussed with emphasis being placed on the motor and electronics.

### INTRODUCTION

Danfoss has manufactured hermetic refrigeration compressors for domestic refrigerators and freezers since 1952.

The latest addition to the Danfoss compressor programme is type BD 2,5 which operates on 12V and 24V DC mains.

It is designed for use in refrigerators up to 120 l and freezers up to 80 l, primarily for leisure applications, for example, boats and caravans as well as busses and lorries. The new units are based on the pump and pot from our latest standard AC compressor, the TL 2,5, and a brushless DC motor with external electronics.

The new compressors meets our requirements for:

1. Low noise- and vibration level
2. High COP value
3. Long life
4. Hermetic system

In the following, the motor and electronics will be dealt with.

### MODE OF OPERATION ( figs. 1 and 2 )

The motor is a brushless, two- pole DC motor with a permanent magnet rotor.

The stator has a bifilar winding with a central tapping. The two winding halves are connected to the battery via two commutation power semiconductors Tr1 and Tr2.

With the rotor starting position shown in fig. 1, which is due to the presence of the starting magnet, the field created in the stator when Tr1 is switched on, will force the rotor to move until the north pole of the rotor faces downwards. Continued movement is achieved by switching to Tr2 etc.

Switching of the two commutation semiconductors is determined by the position of the rotor. Its position is monitored by a sensor which, via the driver and control circuit, controls the commutation semiconductors.

FIG. 1

MOTOR PRINCIPLE

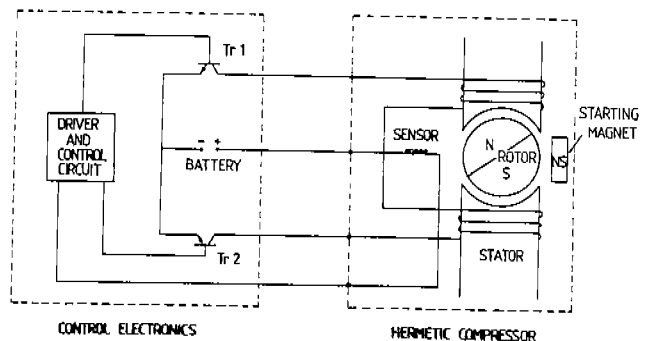
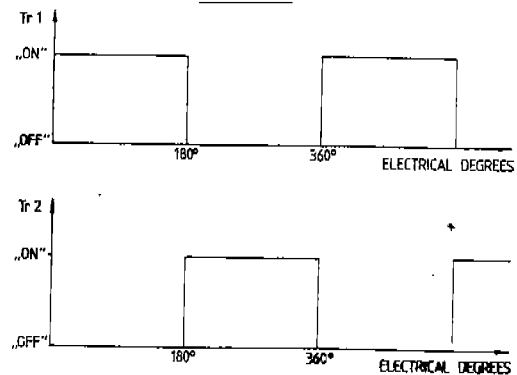


FIG. 2

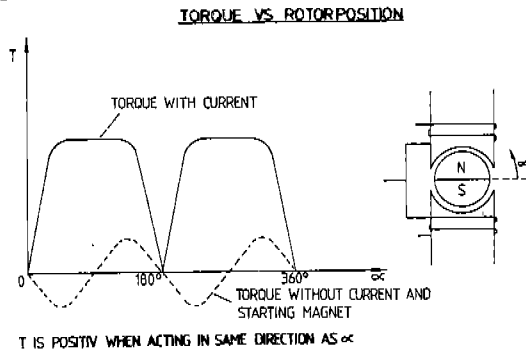
COMMUTATION



## STARTING

The torque of the motor as a function of the angular rotation of the rotor is shown on fig. 3. As will be seen, the motor yields no torque at  $0^\circ$ ,  $180^\circ$  and  $360^\circ$  angular position. These zero points coincide with the natural rest positions of the rotor - thus the motor cannot start. To obtain a starting torque it is necessary to displace the rest positions of the rotor to such an angle that the required starting torque is obtained. this is done by placing a permanent magnet in the stator ( see fig. 1 ).

FIG. 3



## SENSOR PRINCIPLE ( figs. 4 and 5 )

In such applications it is necessary to choose a sensor system which can function at high temperatures in a freon / oil atmosphere and with the vibrations to which it is exposed in a hermetic compressor.

The type chosen comprises a ferrite pot - core with coil. The rotor position is monitored by a 180 iron segment on the end of the rotor which passes close to the sensor, whereupon its goodness  $Q$  is changed from  $\geq 20$  to  $\leq 4$ . The sensor coil is part of an oscillator whose amplitude at this  $Q$  change varies so much that the signal can be used to determine the orientation of the rotor.

FIG. 4

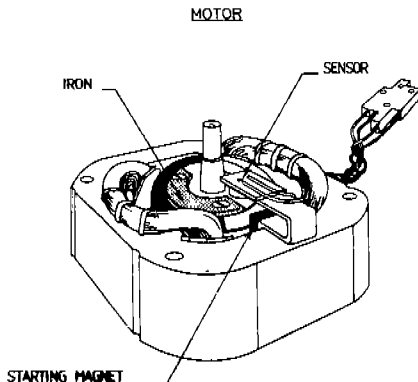
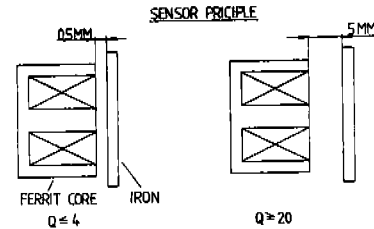


FIG. 5



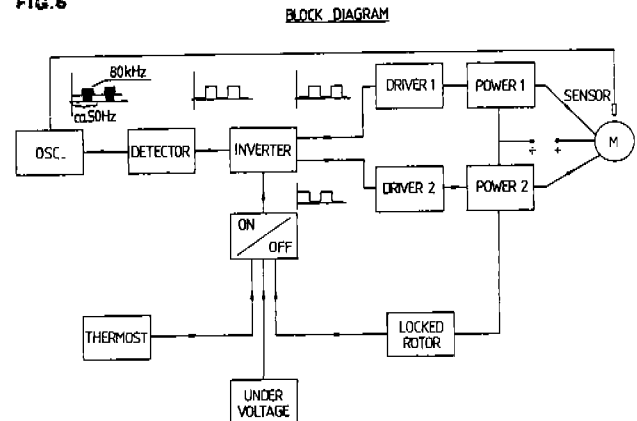
## BLOCK DIAGRAM ( fig. 6 )

The block diagram shows the functions of the electronics unit.

In addition to the already described motor with sensor and commutation semiconductors (power 1 and 2 ), the block diagram shows the oscillator of which the sensor forms a part. The signal from the oscillator is a 80 kHz signal modulated by the motor speed frequency. This signal is send to the inverter via a detector. The inverter forms the two inverted commutation signals. These are send via drivers 1 and 2 to the commutation semiconductors - power 1 and 2.

In addition the electronics has three other functions. A circuit for protection against locked rotor and under voltage and a thermostat function. These three blocks are coupled to a start / stop function which cuts out the motor on a signal from one of them.

FIG. 6

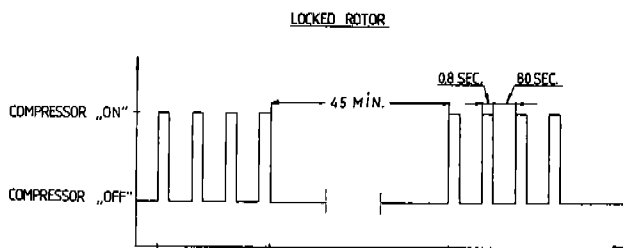


## LOCKED ROTOR ( fig. 7 )

On compressor start a locked rotor condition can occur because of too high a counter pressure. Because of a low motor resistance and the current limitation the power dissipated in the power semiconductors is rather high. To protect the power semiconductors in this situation, the control electronics contains a function that cuts out both power semiconductors within a short time (0,8 sec)

and automatically attempts a restart after a pause (80 sec) to allow pressure equalizing. After four unsuccessful attempts to restart the electronics waits 45 minutes before it again makes four attempts to start, and so on. At low speed, lubrication of the mechanical parts in the compressor ceases. This happens at about 1600 rpms. Speeds lower than this are considered as a locked rotor situation, and handled with the same procedure.

FIG. 7

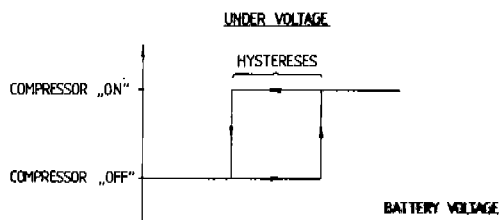


### UNDER VOLTAGE (fig. 8)

To avoid permanent damage to the battery because of heavy discharge, the electronics contains a circuit that cuts off the compressor at a low voltage.

In the 12V version the cut off voltage is 10,5V and the cut in voltage is 11,5V. The hysteresis of 1V prevents oscillations because of voltage drop in the leads.

FIG. 8



### PERFORMANCE OF THE SYSTEM

The torque curve for the motor is shown on fig. 9. The flat section at low speeds is due to the electronic current limitation, which is necessary because of power deposited in the power semiconductors during start and locked rotor and also to prevent demagnetization of the rotor. The current waveform is shown in fig. 10 both at nominal load (2500 rpms.) and high load (1700 rpm). The current jump at commutation from positive to the same negative value is due to the tight coupling between the two windings ( bifilar wound ). Fig. 11 shows the system connected to thermostat and battery.

### PRINCIPAL DATA

Ambient temp.	Operating: 0°C to +55°C	Storage: -35°C to +70°C
Evaporating temp.	-5°C to +55°C	
Condensing temp.	Max. 60°C ( stable )	Max. 70°C ( peak load )
Noise level	≤ 24dBA	
Capacity	(-25/+55°C) 48 watts	(-23,3/+55°C) 183 Btu/h
Power input	53 watts	55 watts
COP	0.9	
EER	3.3	
Current { 12V } { 24V }	4.5 Amps 2.25 Amps	4.6 Amps 2.3 Amps

The 12V compressor consumes approx. 20 Ah/24 hours in a 50 l refrigerator at 5°C cabinet temperature, insulated with 50 mm polyurethane and at 20°C ambient temperature.

FIG. 9

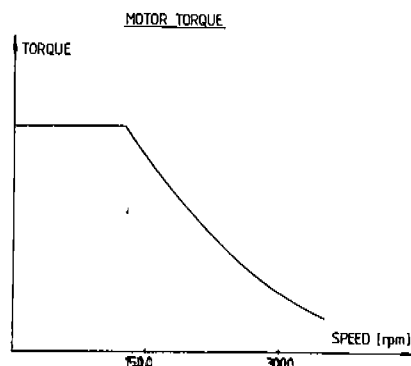


FIG. 10

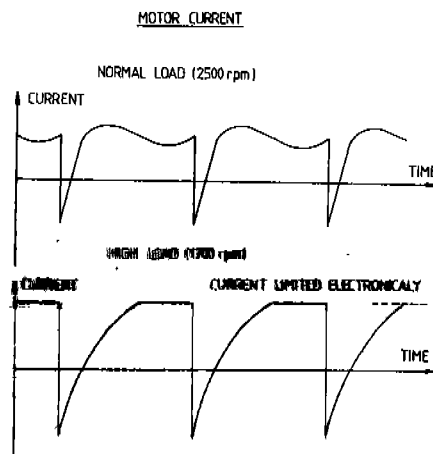
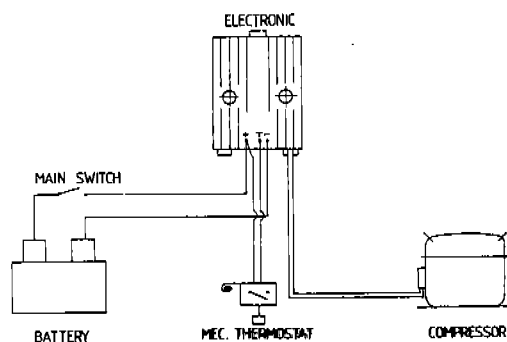


FIG.11



# CONCLUTION

With the chosen technical solution based on a standard well known pump unit and a new developed brushless DC motor with electronics, we have achieved a system that meets our requirements.

An important factor for a system like this is the reliability under different conditions.

The system has been successfully tested in several applications.

In sailing boats, motor boats and fishing boats it has proven its ability to work under large angles of heel and whats very important- it does not interfere with radio and navigation systems on board.

In lorries and busses it has been tested specially for the ability to work under hard mechanical conditions. The BD compressor has withstood very high temperatures and has resisted the effects of poor roads during 200.000 km in a lorry travelling in contries like Spain and Saudi Arabia, and a 20.000 km English expedition through Afghanistan.